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1891. CHARLES RABOT, a Frenchman, in the *Châteaurenault*, starting from the French fishing station in Faskrudsfjord on the east coast of Iceland, was turned back by the ice barrier. He was accompanied by Auguste Gratzl, an Austrian, of the expedition of 1882-3. Their object was to examine the condition of the stores left there in 1883.*
1892. BIENAIMÉ and RABOT, French, again accompanied by Gratzl, in the *Manche*, visited Jan Mayen, entered Mary Muss Bay, and effected a landing on the 27th of July. They stopped but a few hours.
1911. STACKHOUSE Expedition in the *Matador* reached the island on August 11th, It is the purpose of this party to return in 1912, complete the survey of the land, make ocean soundings and, if the ice permits, make the Liverpool coast of Greenland.

* Greely, Handbook of Arctic Exploration, in referring to this expedition, places Faskrudsfjord, a fiord in Iceland, in Jan Mayen.

HANGING VALLEYS OF THE YOSEMITE*

BY

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COMPARISON OF THE YOSEMITE WITH OTHER VALLEYS.

The Yosemite Valley has often been compared with other valleys in an attempt to throw light on the question of its origin. Such comparison, to be of value in the present discussion, must be made between similar valleys which are known to have developed under different conditions. It is clearly inadmissible, for example, to compare the Yosemite with other similar valleys which have also been occupied by glaciers; or with V-shaped gorges in non-glacial regions. For this reason the comparisons mentioned by Turner (318-319) all seem to me inappropriate. So far as can be learned from maps and descriptions, every one of the valleys mentioned by him was either certainly or probably occupied by ice; or has no typical hanging tributary valley; or is a V-shaped young gorge with narrow bottom. Similarly, the discussion of hanging valleys given by the same author on an earlier page (271) is unconvincing, inasmuch as the hanging valleys cited are very short, or have partially graded their lower courses; and all are tributary to a main stream which occupies a narrow-bottomed V gorge of pronounced gradient. They

* Concluded from p. 837, November *Bulletin*, 1911.

are in no sense comparable with the hanging valleys tributary to wide open valleys, such as the Yosemite, which appear to afford strong evidence in favor of glacial erosion.

Instead of disproving the glacial origin of the Yosemite, the comparison of valleys suggested by Turner really affords strong evidence in favor of the theory of glacial erosion. It is no mere coincidence that of the six valleys named by that writer the two most unlike the Yosemite have presumably suffered little or no glaciation, whereas the four most like the Yosemite served as the outlets of extensive glacial basins. The areas of these basins may be determined roughly by drawing boundaries which shall enclose all of the strongly glaciated region tributary to the several valleys. Although this does not take account of the passage of ice from one basin to another across the present divides, the method is sufficiently accurate, when applied to alpine regions of strong relief, to enable one to discriminate between profoundly and slightly glaciated basins, and between basins which favor extensive erosion of the master valley, and those which do not.

The valley near Sugar Loaf, on the South Fork of the American River, is so little like the Yosemite that the contour map leaves one in doubt as to why they should be compared; for the contours represent a V-shaped gorge without hanging valleys, although a few of the tributaries have their lower courses somewhat over-steepened. The basis of comparison with Sawmill Canyon is simply that the latter "under favorable circumstances would widen out into a Yosemite"; but since this questionable statement involves the very point at issue, the comparison is not permissible. On the other hand, the small valley on the Middle Fork of Stanislaus River at the mouth of Niagara Creek bears some resemblance to the Yosemite by reason of its steep walls and flat floor; but the contour map shows such marked evidences of glaciation in the headwater portions of streams draining into this valley that it seems quite probable that a glacier traversed the valley and gave to it its peculiar form. The area of the glacial basin is smaller in this case than in the others mentioned below, and this may account for the small size of the glacial trough on the Middle Stanislaus. Hetch Hetchy Valley is truly another Yosemite, larger than the valley on the Middle Stanislaus, because it is the outlet of a larger and more profoundly glaciated basin. It is smaller than the real Yosemite, because its glacial basin, while very large, is very asymmetrical (Fig. 3 a). The ice streams, instead of flowing comparatively short distances to the center of the basin and there uniting to form a large and powerful glacier, as in

the case of the Yosemite Valley (Fig. 3 b), were compelled to flow almost clear across the basin before reaching the master valley, which they joined at various points along its course, instead of concentrating at one point. It should be remembered, also, that part of the ice of the Hetch Hetchy basin crossed the divide into the

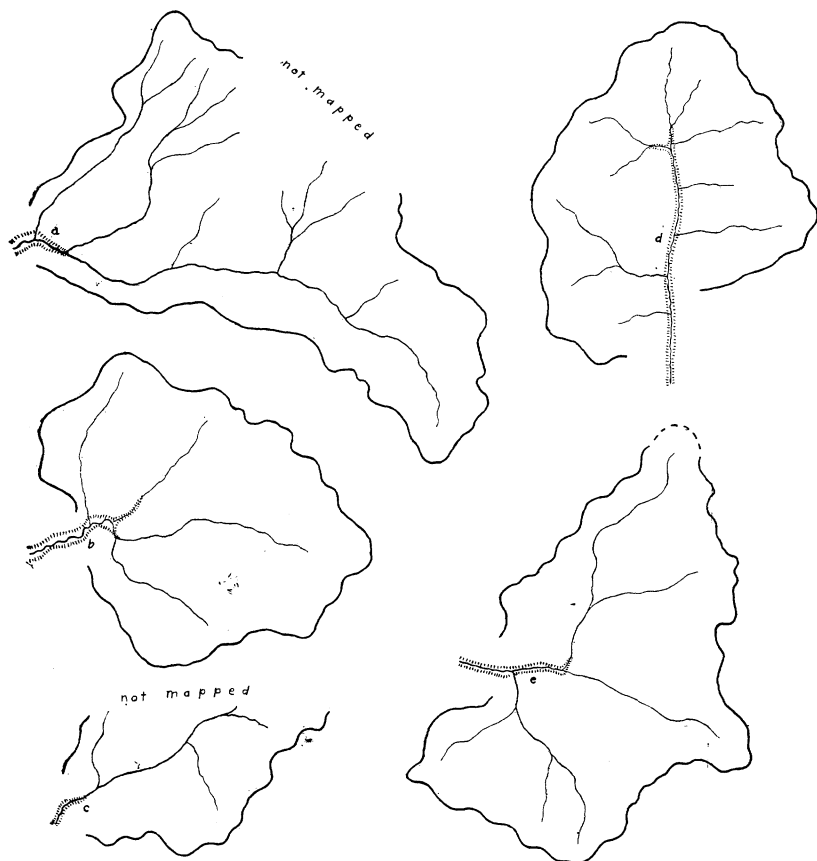


FIG. 3.—Sketch maps showing relation of the Yosemite and other similar valleys to their glacial drainage basins. Stream lines indicate general direction of glacial drainage. Based on U. S. Topographic sheets. No account is taken of ice entering basins from beyond present divides. *a*, Hetch Hetchy Valley; *b*, Yosemite Valley; *c*, Tehipite Valley; *d*, Kern Cañon; *e*, Grand Cañon of Kings River.

Yosemite basin; but I believe the shape of the area draining into the Hetch Hetchy is the more important factor in determining the less profound glaciation of that valley.

Tehipite Valley is likewise the outlet of a basin (Fig. 3 c) in which glaciation was evidently very pronounced. While the glacial

trough form is marked, this valley is less striking than the Yosemite, presumably because its glaciated basin is less symmetrical and permitted less concentration of the ice streams than was the case with its more fortunate neighbor. The Grand Canyon of Kings River, the last of the valleys mentioned by Turner, is the outlet of a splendid glacial basin (Fig. 3 e); consequently it is itself a splendid glacial trough. One might add to the above list Kern Canyon, which has the trough form well developed, because it is the outlet of a basin (Fig. 3 d) in which glaciation was profound, and is so shaped as to admit of a fair concentration of ice streams. Yosemite Valley owes its preëminence to the favorable combination of several elements: (1) a remarkably symmetrical basin, which was (2) profoundly glaciated, and which permitted (3) intense concentration of ice streams, one of which was augmented by (4) overflow ice from a neighboring basin. Variations in the country rock doubtless played their part in giving to the different troughs different degrees of perfection; but I regard rock differences as of less importance than differences in the size, shape, and extent of glaciation, of the basin for which the troughs serve as outlets.

Turner has suggested (p. 318) that the Yosemite Valley may have acquired a depth of 1,000 feet by the beginning of the Pleistocene, and that this "lessens the difficulty of accounting for the present depth of the Yosemite and of other canyons of the southern Sierra." The elevation of the Merced River previous to glacial overdeepening was, as shown above, from 2,000 to 2,500 feet above the present level of the stream, or between 6,000 and 6,500 above present sea level. This may have been 1,000 feet below the higher parts of the imperfectly developed peneplain. In any case, the present hanging valleys appear to have been graded with reference to that elevation of the Merced, and the indications are that the Merced at that time occupied an open valley as did the tributaries. The difficulty which confronts the theory of stream erosion of the Yosemite is not the absolute depth of the canyon, but rather the relation of the broad-floored main valley to the hanging valleys. This difficulty is not lessened by imagining an earlier or later date for the initiation of canyon cutting.

The character of Tenaya Canyon has always been a serious difficulty in interpreting the Yosemite as a stream carved valley. Tenaya Creek, with a drainage area little if any larger than that of Yosemite Creek, flows through a wide open valley to an accordant junction with the aggraded floor of the open Yosemite Valley, instead of dropping 2,000 feet or more from a hanging valley. Assuming nor-

mal stream erosion, it is hard to see why one small tributary should be able to reduce its valley to grade and to open out its valley floor to a considerable width, while a similar tributary near by has made but a small beginning on so vast a work. Mr. Theodore Solomons has suggested that the Lyell Fork of the Tuolumne and its branches were formerly headwaters of Tenaya Creek, but have been captured by the Tuolumne River. This would account for a formerly larger volume of Tenaya Creek, under which condition the cutting of the canyon would seem less remarkable. Turner (276-277) discusses this possibility, but on the evidence of river gravels dismisses it as "very improbable." Even if we suppose that the Lyell Fork drainage formerly came through Tenaya Canyon, we still encounter difficulties in explaining the relation of the canyon to the hanging valleys. On the other hand, if we accept the very reasonable hypothesis that during the glacial period much ice from the Tuolumne Valley crossed the low divide into the Tenaya Basin, and thus agree with Turner (305-306) and Gannett (87) that the Tenaya Glacier was the largest ice stream which entered the Yosemite Valley, we have, on the theory of glacial erosion, an adequate explanation for all the features observed. The Tenaya Canyon owes its U-shaped cross-profile, and its depth below the hanging valleys to glacial erosion. The canyon is deeper and more imposing than other valleys tributary to the Yosemite, because it was carved by the most powerful tributary glacier. The small Tenaya Creek is even much deeper than corresponding portions of the main Merced River in the Little Yosemite Valley, because the Tenaya Glacier was larger and more powerful than the Little Yosemite Glacier.

THE LONGITUDINAL PROFILE OF THE MERCED RIVER

Reference has been made above to the fact that some of the streams entering the Merced west of El Portal, as, for example, Bear Creek and the North Fork of the Merced, have over-steepened lower courses. They join the Merced with accordant junctions, but a short distance back from the main river show an increase in gradient, while their upper courses are again of gentle slope. One should not be surprised to find a comparable feature in the main river itself, farther up stream. For while an even tilting would initially increase the gradient of the main river uniformly throughout its course, greater volume would allow the lower course to intrench itself more rapidly. If to difference in volume we add difference in rock resistance, it is easy to see how one part of the stream flowing in weaker

rock might intrench itself more rapidly than a part up stream on more resistant rock, thus developing a locally steep gradient which would gradually retreat up stream. Something of this nature is shown in the longitudinal profile above (east of) El Portal. It should be remembered that, west of El Portal, the valley of the Merced is unglaciated, while east of the western end of the Yosemite, the valley has been profoundly glaciated. Between these two points, El Portal and the western end of the Yosemite, the valley has been traversed by glaciers to some extent, and shows the effects of glacial erosion very distinctly near the Yosemite, but to a decreasing extent toward El Portal. Had the pre-glacial Merced possessed a well-graded profile in this region, we should expect to find now, as a consequence of glacial erosion, a gradual decrease in gradient above El Portal, until the gradient finally became approximately flat, or even reversed, in the Yosemite Valley, where glaciation was most profound. Instead, we find a very pronounced steepening of the gradient above El Portal, similar to the steepening observed in the lower courses of the non-glaciated tributary streams farther west. It is evident that before glaciation the main river had not completely graded its course, although it had pushed the over-steepened zone as far up stream as El Portal. From this point the profile rose rapidly to a level some 2,000 feet above the main portion of the Yosemite Valley, as shown by the position of the hanging valleys. The western part of the Merced was then entrenched, the eastern part still flowing on the uplands. Glacial erosion has greatly altered the profile of the eastern part, but some trace of the pre-glacial conditions persists in the over-steepened profile east of El Portal.

VALLEY WIDENING IN JOINTED ROCKS

One of the most evident relations in the present topography of the Yosemite Valley is the control of joint planes upon weathering and erosion. Impressed by the remarkable form of the Yosemite Valley as a whole and by the important influence of jointing upon the form of the valley walls, some observers have genetically connected the two, seeking to explain the former by the latter. Unfortunately, no one who supports this view has set forth in detail just how stream erosion on jointed rocks can develop valleys essentially different from those developed by stream erosion on unjointed rocks. A brief analysis of this phase of the Yosemite problem may not be amiss. Let us first consider the process of valley development in massive, unjointed rocks.

If a main stream incises itself with such rapidity that the walls weather back but slightly before a deep trench is cut, the stream will come to flow in a narrow chasm with more or less nearly vertical walls. The width of such a chasm is little if any greater than the width of the stream. Tributaries may entrench themselves more slowly, and so give rise to lateral hanging valleys. If we imagine weathering to proceed more rapidly, the walls of this valley will retreat as the stream cuts downward. Two factors operate to make the higher portions of the walls retreat farther than the lower portions. First, the higher portions are exposed to the influence of the weather for a longer time. Second, a greater transverse breadth of rock is in unstable equilibrium near the top of a narrow chasm than near the bottom. Just at the stream level no rock is in an unstable position, and weathering must proceed very slowly where gravity has little or no chance to remove the rock fragments. Hence, valley widening due to weathering is at a minimum at stream level. A little above the stream level a narrow segment of rock on each side is liable to fall down into the stream as fast as its parts are loosened by weathering. Here the valley may be widened slightly, due to weathering alone. The corresponding segment of rock which is liable to weather from still higher levels is much greater; so that the top of a valley may weather to a width of a mile or more while the bottom remains the width of the stream itself.

The above is perhaps an over elaborate statement of the well recognized relation between stream incision and weathering which results in the V-shaped cross-profile of most young stream valleys. It should not be inferred that the young stream does no lateral cutting while entrenching itself, for lateral erosion lends its aid to weathering in producing the width of the valley. But during the youth of a stream, when down-cutting is active, the effect of lateral cutting is ordinarily obscured by the far greater work of weathering. It is fair to say that during youth, valley deepening is largely due to stream cutting, valley widening largely due to weathering; whence it follows that a young stream cannot develop a broad, flat valley floor. Beginning with maturity, valley deepening becomes of small importance, and valley widening may be due more to lateral cutting than to weathering. A flat valley floor, many times the width of the stream, may be developed.

Let us now consider whether the above principles are modified in case the valley walls are intersected by joint planes. In order that joint planes may produce the greatest effect upon erosion forms, they must be neither too widely nor too closely spaced. If too widely

spaced, much of the valley will be carved in massive, unjointed rocks. If too closely spaced, the rock mass will be so badly broken up as to constitute an area of relatively non-resistant material of fairly uniform character; and only minor features of form will show the effect of joint control. Let us imagine, then, a region of massive rock, such as granite, traversed in several directions by joint planes of such frequency as to make the included joint blocks of large, but not excessive size. The process of weathering will certainly be facilitated by the jointing; but it does not appear that this structure can produce any essential modification of the ultimate result. Joint planes sloping toward the stream will allow weathering and gravity, to remove the granite blocks which are in an unstable position more quickly than would weathering in unjointed granite. The open V-shaped cross-profile will be the more quickly attained. But the large joint blocks at stream level are in a stable position, and no process of normal weathering is known which would pry them out of so secure a place against the pull of gravity, in order to widen the bottom of the V. They cannot be washed away by the stream itself. Whether massive or broken by joint planes, the rocks in the bottom of a gorge must wear away little by little, even though great joint blocks may fall from unstable positions high up on the valley walls. This holds true, no matter what varieties of jointing we imagine to exist. Vertical joints will leave temporary, vertical faces wherever a joint block falls from place. A vertical face is unstable, however, and must slowly weather back to a more gentle slope. If a stream quickly incises itself in vertically jointed rocks, we may have a narrow chasm with vertical walls. But as soon as weathering makes its effects apparent, we must have a markedly greater width at the top of the gorge than at the bottom, the latter remaining narrow so long as the stream is youthful.

Returning to the case of the Yosemite Valley, we observe an undoubted characteristic of youth in the hanging valleys. Yet the width of the main valley cannot be largely due to weathering, since the valley floor is broad and flat. Joint planes, such as would facilitate weathering, are present in the valley walls, and are evidently influencing the weathering now in process. But no process of weathering in jointed rocks can account for the great width of the valley floor. The hanging valleys confirm the conclusion that the width of the Yosemite is not due to weathering; for stream courses descending a valley wall are worn back, by erosion and weathering combined, at a faster rate than are the interstream areas where weathering alone is active. If the walls of the Yosemite had retreated by weathering, the

tributary streams, and especially the larger ones, should have cut so far back from the main valley as to have destroyed the hanging valley effect. Instead, we find the tributaries cascading down the main valley walls, or descending in slight re-entrants formed by the rapid breaking away of joint blocks which occupied unstable positions in the steep valley walls.

One can conceive that valley widening in jointed rocks due to lateral cutting by a shifting stream of early mature age might give a flat-floored, steep-walled valley; for when down-cutting is reduced to a comparatively negligible quantity, lateral cutting at approximately one level will widen the valley floor by undermining the valley walls. Granted the favorable combination of a graded, shifting stream eroding laterally with vigor, and rock walls which weather slowly in comparison with the rate of undercutting and which are traversed by vertical planes of weakness, we can imagine the removal of the valley walls to take place in such a manner as to leave vertical faces on the retreating cliffs.

That the broad floor and steep walls of the Yosemite Valley cannot have this origin is evident from the existence of the hanging valleys. The latter would have been reduced to grade before the Merced River could have accomplished so great a work as the grading of its course and the undermining of its walls by lateral cutting. The existence on the same stream of hanging valleys, a characteristic of young streams, and an open valley floor, a characteristic of mature streams, demands a special explanation.

There is a special set of conditions which may possibly constitute an exception to the above statement. If a stream follows a belt of very weak rock, between masses of very resistant rock, and an uplift permits rapid entrenching, the stream may have time to broaden its valley floor in the weak rock before the tributaries, held up on the hard rock, advance far in the process of grading their courses. That the combination of favorable circumstances necessary for the production of hanging valleys of this type is exceedingly rare, is evident from their almost complete absence in regions of normal stream erosion, even where alternate belts of resistant and non-resistant rock exist. There is no evidence that any strong contrast in rock resistance existed between the granite removed to form the Yosemite Valley and the granite which remains in the valley walls. Jointing will not explain the phenomena unless we imagine a zone of granite so badly jointed and crushed as to give a belt of weak material of the width and pattern of the Yosemite Valley, all of which has been quickly removed, leaving granite of markedly different character in

the present walls. A far more reasonable hypothesis is to regard the Yosemite Valley as one of the many open main valleys with hanging tributaries which characterize every region of Alpine glaciation, and which are reasonably interpreted as the product of glacial over-deepening of pre-existing river valleys.

It may be pointed out that the remarkable effects of jointing observed in the walls of the Yosemite are indirectly due to glacial over-deepening and over-steepening. Not until glacial erosion had made the steep-sided trough, was full opportunity given for the joint blocks to fall from place leaving the angular re-entrants and vertical faces which form such an important element in Yosemite scenery. Weathering and gravity have worked to great advantage in the recent past, and the resultant features are bold and striking. In the future, as the walls wear back to more gentle slopes and the more stable position of the joint blocks causes them to waste gradually away instead of falling in large masses from the cliffs, the valley walls will become cloaked with debris, the bold features of today will give place to more flowing, graded profiles, and the grandeur of Cathedral Rocks, Three Brothers and Half Dome will be a thing of the past. The influence of jointing on weathering is thus to be interpreted as an indirect effect of the glacial origin of the valley, rather than as an important agent in the formation of the valley.

THE NOTCHES BESIDE THE FALLS

As an observer stands in the Yosemite Valley and views the cataract of the Yosemite, Lower Yosemite, Illilouette, Vernal or Nevada Falls, he notes that beside each fall is a deep notch which the stream curiously avoids, to fall over a sheer cliff, as if to provide for man the most stupendous spectacle possible. Branner has given us a good description of this peculiar topographic feature (547-553), and has attributed the formation of the notches to the action of the several streams during a time when they were displaced from their normal positions by ice. A glacier occupied the bottom of each valley, forcing the stream to take a course some distance to one side, where it was held between the ice and the valley wall. While in this position the notch was cut. When the glacier disappeared the stream returned to its former position, leaving the notch deserted. Inasmuch as the stream cut the notch back faster than the glacier eroded its channel, it was argued that glaciers must have very little eroding power, and that the Yosemite Valley must therefore be the result of normal stream erosion in jointed rocks.

The present visitor to the Yosemite may profit by Matthes's excellent topographic map, which was not available when Branner wrote his account of the notches. An inspection of the map, suggests the necessity of some modification of this author's interpretation, and the field evidence confirms the suggestion. The notches beside Lower Yosemite Falls, Illilouette Falls, and Vernal Falls do open up at a higher level in the floors of the valleys in which they were cut, as required by Branner's theory. But above these notches are no signs of abandoned stream channels, and in the notches are no signs of stream erosion. On the other hand, the notches are seen to result from the normal weathering away of granite along oblique joint planes. When

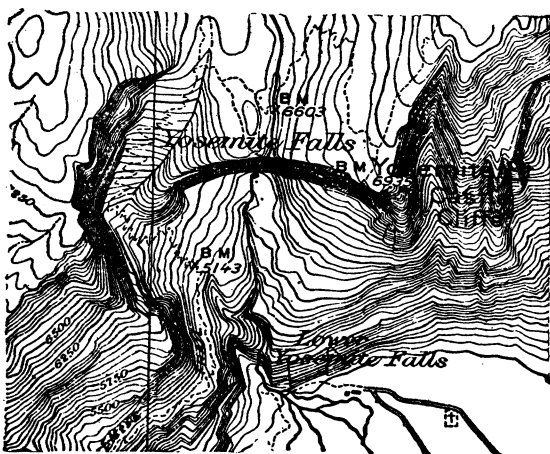


FIG. 4—Yosemite Falls. Showing abandoned stream-carved notch to the west, through which the trail passes. West of the Lower Yosemite Falls is a notch due to weathering along joint planes.

we remember that over-deepening of the main valley left the steep valley walls (and likewise the rock steps in the main valley) in an unstable condition, it is easy to realize how the granite would break down rapidly wherever cut into blocks by jointing; and how successive blocks breaking from the lips of hanging

valleys would leave oblique scarps in case principal joint planes intersected the axes of the valleys at oblique angles. An oblique scarp meeting the valley wall on one side of the stream would give such a notch as we find at each of the three falls in question. The notches at Vernal Falls (Fig. 6) and Lower Yosemite Falls (Fig. 4) are developed on NW-SE joints belonging to the same system as the joint which gives form to the southwest face of Mt. Broderick and Liberty Cap. The notch at Illilouette Falls (Fig. 5) is due to a NE-SW joint plane, similar in direction to those which appear at Nevada Falls and on the steep face of Half Dome.

The notch at Nevada Falls (Fig. 6) is undoubtedly a stream carved notch, but it does not open on the side of the valley wall as represented in Branner's sketch map. Indeed, it opens so squarely in the

bottom of the valley above the falls that a small part of the water of the Merced River escapes through the notch, diminishing the volume of the falls by so much. The size and form of the notch, and the large water-worn boulders found in it, indicate that the entire river passed through it at one time. It does not seem necessary to invoke glacial displacement to get the stream in the notch, since part of the stream flows naturally into it even now. A simpler interpretation is that the notch was cut in the bottom of the valley under normal conditions, and that a slight displacement, possibly a glacial advance, turned the stream into its present course over the cliff.

The notch beside the Upper Yosemite Falls is similar in origin to that beside the Nevada Falls. Yosemite Creek formerly flowed through the notch, but was shifted to its present position, doubtless by a late advance of the Yosemite Creek Glacier. It would seem that Yosemite Creek acquired its abnormal position earlier than did the Merced River at Nevada Falls, since the creek has had time to entrench itself to a noticeable extent, although the probable former course of the creek may still be observed in the depression above the notch which is followed by the trail for some distance.

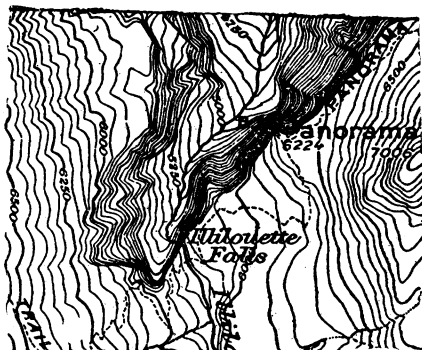


FIG. 5—Illilouette Falls. Showing notch due to weathering along joint planes.

The existence of two distinct types of notches beside the falls in the Yosemite region is clearly shown by Matthes's map, from which the above figures are reproduced. In fact, my first appreciation of their dual character came from a study of the map. After this paper had been prepared for presentation at the geological meetings in Boston during the last convocation week, I learned that Matthes recognized the dual character of the notches during his field work.

Returning to the question as to what evidence the notches offer concerning the relative efficiency of stream and glacial erosion, it should be noted that the notches at Lower Yosemite Falls, Illilouette Falls and Vernal Falls afford no evidence on this question since they were formed independently of stream erosion. The notches at Upper Yosemite Falls and Nevada Falls were carved by stream erosion after the main valley had been over-deepened, and before the

ice advance which displaced the streams to their present positions. According to the theory of glacial erosion the main valley was over-deepened by ice action. Hence the notches are of inter-glacial age— younger than (part of) the glacial deepening of the main valley, and older than the glacial displacement of the streams to their present courses.

Post-glacial cutting has formed only insignificant notches where the streams now pass over the ledges. Making no allowances for

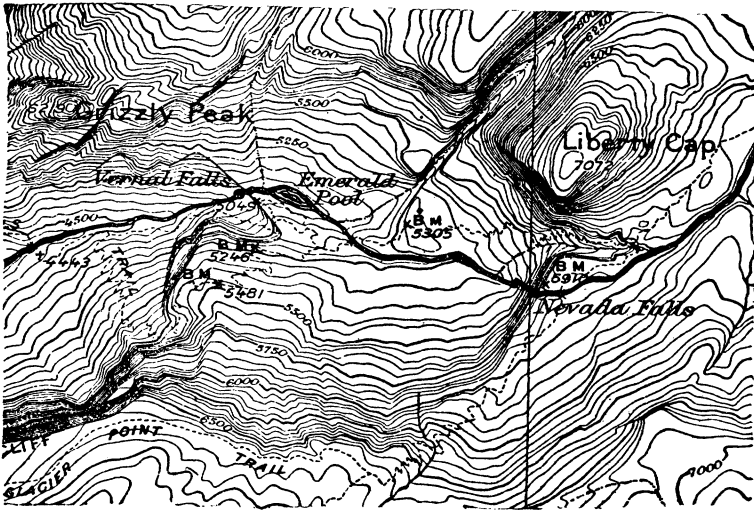


FIG. 6—Vernal Falls and Nevada Falls. Just south of Vernal Falls is a notch due to weathering along joint planes, while north of Nevada Falls is a notch carved by the stream. Trails pass through both of these notches.

difference in volume and load of streams in inter-glacial time, it would appear from the relative sizes of the notches that post-glacial time has been short as compared with inter-glacial time. On this interpretation the notches afford no evidence one way or the other as to the efficiency of glacial erosion.

CONCLUSION

The Yosemite Valley is a young glacial trough of great depth, whose walls of jointed granite are in a youthful stage of weathering, and whose floor has been maturely aggraded by the main stream. The position of the trough was determined by a preëxisting river valley which guided the advancing glacier. Extensive glacial erosion was favored by the shape of the glacial drainage basin, which permitted different ice streams to converge at one point and form the

unusually vigorous Yosemite Glacier. Glacial over-deepening exceeded 2,000 feet in the Yosemite region, and produced the remarkable hanging valleys for which the region is famous. Glacial over-steepening produced the steep valley walls, and made possible the effective weathering along joint planes, to which the details of cliff sculpture are due. Many of the notches in the lips of the hanging valleys are due to the joint-controlled weathering; but some are stream carved notches, deserted by their streams because of glacial interference. Both types of notches are expectable features in the side of a glacial trough located in jointed rocks.

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THE ERUPTION OF TAAL VOLCANO

The following account of the eruption of Taal Volcano on January 30, 1911 is abridged from a paper prepared by Mr. Walter E. Pratt.*

Taal Volcano, in southwestern Luzon, "began throwing out steam and mud on January 27, and continued in eruption with increasing violence during January 28 and 29, culminating in an explosive out-

* *The Philippine Journal of Science*, Vol. VI, 1911, No. 2, pp. 63-83. 3 figs. in text and 14 plates of photo-engravings and maps.